# Avalanche rescue beacon testing

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**Abstract:** The performance of four types of avalanche rescue beacons was tested during the winter 2001 in Switzerland. During the first field test the search times were compared. The second test focused on range measurements to determine search strip width. Results show that maximal range of different beacons varies between about 25 and 100 m. Differences in search times are as well significant, but relatively small compared with the total time for recovery of a buried victim. A recently proposed method to determine search strip width based on maximum range measurements in coaxial antenna orientation was verified and can be recommended.

**Keywords:** avalanche accident, avalanche rescue

## 1. Introduction

Avalanche rescue beacons have become standard equipment for the winter mountain traveler. With the appearance of digital beacons or transceivers, and the growing variety of beacons, the need arose for independent testing of this type of rescue equipment. Although there is a European standard (ETS 300 718) for manufacturing beacons, there are nevertheless substantial differences in performance between different brands. However, testing the performance is not straightforward. Performance can be defined very differently, with the consequence of largely varying test results.

The first and most comprehensive performance test had been initiated in 1998 by ICAR (International Commission for Alpine Rescue) (Krüsi et al., 1998; Schweizer, 2000). Since then various smaller tests have been done under varying conditions (Sivardière, 2001). In the winter 2000-01 two large field tests have been performed in Switzerland. Search times in one and range in the other test have been determined for four different brands of beacons from the US and Europe (Fig. 1). Both parameters tested are important. Search time integrates many specifications as efficiency and ease of handling, whereas range strongly influences the search strategy by defining the width of a search strip. The tests have been designed to ensure best reproducibility.

Besides testing the performance of several modern beacons, the additional objective was to verify a recently proposed method to determine the width of a search strip. Meier (2001) proposed to measure the maximum range in coaxial position, and to calculate the search strip as the mean minus two times the standard deviation ($m$-2$\sigma$) of the maximum range (so called 98% maximum range). This determination requires that the searching person actively rotates the beacon during the signal search (or primary search), and already takes into account not optimal user co-operation, not optimal battery level and some reduced performance due to temperature effects.

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## 2. Method

Three of the beacons tested were modern types (Mammut Barryvox, Ortovox M2, Tracker DTS); one was used as a reference beacon (Barryvox VS 2000, or so-called "old" Barryvox). The beacons were standard devices as could be bought in the winter 2000-01. Accordingly, the results described below represent the state of beacons as available in 2000-01. Any improvements made by the manufacturers since then are not reflected in the results presented below.

### 2.1 Search time

Search times were measured on 7 February 2001 at

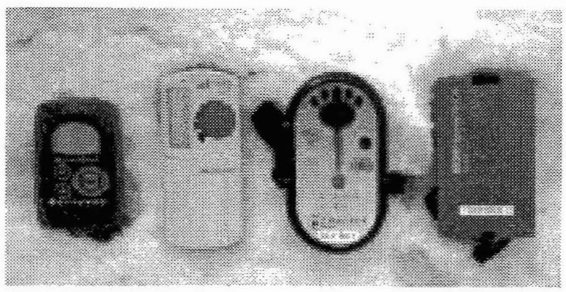

*Figure 1: Beacons used in the two tests in February and April 2001 in Switzerland: Mammut Barryvox, Ortovox M2, Tracker DTS and VS 2000 ("old" Barryvox), from left to right, in alphabetical order.*

Engstligenalp, Bernese Oberland, Switzerland. The test was initiated by the Consumer Magazine of the Swiss National Television Broadcasting Company, designed by the two mountain guides Emanuel Wassermann and Michael Wicky, and supervised by SLF (Schweizer et al., 2001).

The search took place on a large flat plane, about 700 m × 700 m in size on 16 search fields each with one beacon buried. The search fields were about 100 m apart and were 50 m × 70 m in size (Fig. 2), since this is about the typical size of the avalanche deposit of a human-triggered avalanche (Schweizer and Lütschg, 2001). On 8 out of the 16 search fields the beacon was buried near the center line of the field, on the other 8 fields it was close to the farer end. So, in half of the fields the beacon was about 35 m from the starting point, in the other ones about 70 m away. The transmitting beacons were all Barryvox VS 2000, buried 70 cm below a wooden panel of 40 cm × 80 cm in a 45° inclined position. The beacons were buried, equipped with new batteries, the evening before and the fields then planed with a snow grooming machine.

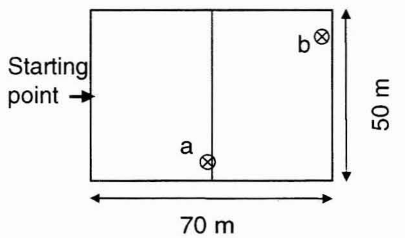


*Figure 2: Search field for measuring search time. On 8 of the 16 fields the beacon was buried near the center line (position a), on the other 8 fields near the farer end (position b).*

The search time was measured from the starting point at the edge of the search field with the receiving beacon still in transmitting mode (so switching into search mode was part of the measured search time), to the time when the searching person had located the hidden beacon, i.e. when the person hit the wooden panel with the avalanche probe. If the searching person could not find the buried transmitting beacon within 15 minutes, the search was stopped.

This design allowed that 16 persons could search at the same time. Each person then searched four times with each of the four different brands of beacons, so that 64 measurements per type of beacon, and 256 searches in total, resulted. The sequence was arranged such that each person only did search once on a specific field. In general, much care was taken to avoid any bias by the design of the test. All the 16 persons searching were novices, students from the local school. On each of the 16 fields there was a supervisor overseeing each test. Accordingly 32 persons were involved in the test.

After a general introduction the searchers were introduced to each of the four types of beacons for 10-15 minutes by a representative of the manufacturer, or an experienced guide, just before they started to search four times with a given brand. The group of four who had searched four times with a given brand was then split up, and the groups were rearranged to avoid that a given type of beacon would be rated highly because of the inherent learning effect during the day.

### 2.2 Range

The range was measured on 9-11 April 2001 about 6 km up a side valley from Davos, Switzerland. The test was organized by SLF (Schweizer, 2001; Schweizer, 2002).

Two methods were used to measure range. The first method was previously applied by Krüsi et al. (1998) and is used to measure the medium range by walking pass a transmitting beacon with a random antenna orientation (Fig. 3). In the optimal case the parallel antenna orientation can be reached.

Four units of the VS 2000 beacon were alternately used as transmitting beacon. The antenna position was changed after 32 measurements, as well as the unit. The searching person follows a line, marked with a tape-measure, and slowly rotates the beacon to achieve the parallel antenna position. When the searcher has the first reliable signal, the distance from the center line is read and recorded. For the Mammut Barryvox and the Ortovox M2, this has been done for the optical and the acoustical search unit, resulting in a smaller optical and a larger acoustical range. Knowing the distance of the search line from the transmitting beacon, the range can

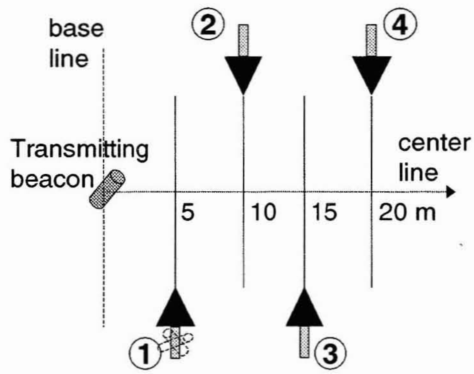


*Figure 3: Test design for the measurements of the medium range by passing by. The transmitting beacon has a random antenna orientation. The receiving beacon is rotated by the searching person to achieve optimal antenna coupling (parallel position at best). The search lines are parallel to the base line (transmitting beacon) in 5 m equidistance. Positions 1 to 4 indicate the starting points on the search lines.*

be calculated. This test design is closest to the real situation, but variation in test results can be large, so that a large number of measurements is needed.

On four equidistance search lines four teams of two (one person searching, one recording the results) were searching with a different type of beacon at the same time. After four measurements, one on each search line, the searching person and the recording persons changed tasks. After eight measurements the beacon types were exchanged. Four different units of one single brand were used alternately. For each of the four types of beacons 128 measurements, 512 in total, were made.

The second method, is the one proposed by Meier (2001), and used to measure maximal range in coaxial antenna orientation. The experimental setup was as shown in Figure 4. On two search lines four teams of two persons were approaching the transmitting beacons by holding the receiving beacon in horizontal position such that the antenna orientations of receiving and transmitting beacon were in line. Again, four different units of a given brand were available and exchanged alternately, as were searchers, transmitting beacons, and receiving beacons (see above). A total of 56 measurements per type of beacon, 224 in total, with the VS 2000 as transmitting beacon were performed. In addition, 28 measurements per type of beacon were made with the Ortovox M2 and the Tracker DTS as transmitting beacon. Again, as for medium range, the optical and acoustical range were recorded if available.

### 2.3 Search strip width

With both methods described above to measure range, the width of the search strip, one of the most important properties of a beacon, can be determined.

If measuring the medium range, the search strip width corresponds to twice the so-called 98% medium range ($m$-2$\sigma$), assuming a normal distribution (Krüsi et al., 1998; Meier, 2001; Schweizer, 2000).

Applying the method proposed by Meier (2001) indicates that the width of the search strip corresponds just to the 98% maximal range, as measured with coaxial antenna orientation.

## 3. Results

### 3.1 Search time

One person searching with a VS 2000 did not find the buried beacon within the time limit; a value of 15 minutes was assigned to this measurement. Two persons, one with an Ortovox M2, one with a VS 2000, gave up searching before reaching the time limit of 15 minutes; these two measurements were discarded. Accordingly, the number of measurements is 63 for the Ortovox M2 and the VS 2000.

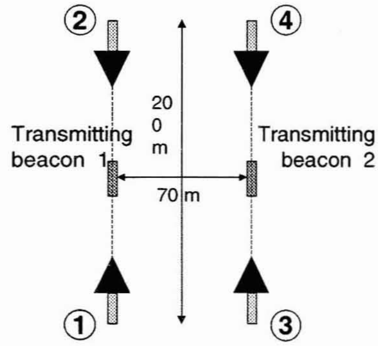


*Figure 4: Test design for the measurements of the maximal range by approaching with coaxial antenna orientation. Positions 1 to 4 indicate the starting points on the search lines.*

Figure 5 shows the distribution of the search times and Table 1 summarizes the results by giving the key statistics. Search times were fastest with the Tracker DTS and the Mammut Barryvox. The results for the Mammut Barryvox and the Tracker DTS are statistically not significantly different (non-parametric $U$-Test, $p$=0.52), as well as not for the Ortovox M2 and the VS 2000 ($p$=0.39). Interestingly, the novice searchers found the buried beacon faster with the Barryvox VS 2000 than with the Ortovox M2.

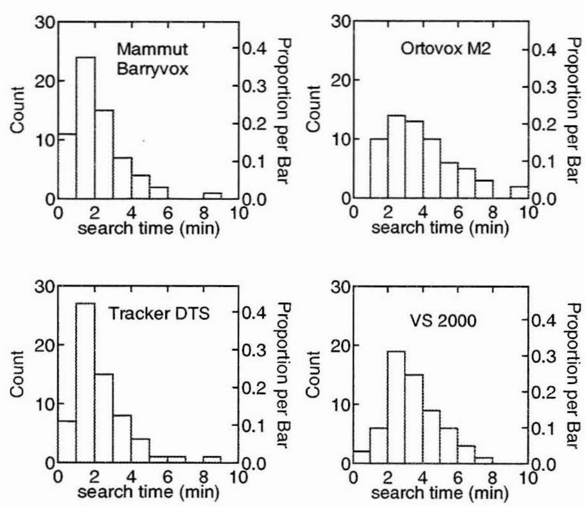


*Figure 5: Frequency of search times for the four different beacons tested. Two cases with search times larger than 10 minutes not shown.*

### 3.2 Range

In the following we only report on the range measurements which have been done with a VS 2000 as transmitting beacon. In general, the results of the measurements with the other beacons that were used as transmitting beacons reduced the average range and

Table 1: *Results of measurements on search time*

| Type of beacon | N | 1st quartile (s) | Median (s) | 3rd quartile (s) |
|---|---|---|---|---|
| Mammut Barryvox | 64 | 67 | 109.5 | 167 |
| Ortovox M2 | 63 | 147 | 214 | 296 |
| Tracker DTS | 64 | 83 | 106 | 173 |
| VS 2000 | 63 | 144 | 187 | 269 |

increased the standard deviation. Accordingly, the search strip width would be reduced.

Table 2 compiles the results of the medium range measurements. A normal distribution has been fitted to the frequency distribution in order to calculate the search strip width subsequently. Goodness of fit was generally high, as indicated by the small difference between median and mean.

The results of the measurements on the maximum range are shown in Figure 6. The frequency distributions are quite different, in particular in regard to the standard deviation (Table 3).

### 3.3 Search strip width

Based on the results of the range measurements as presented above the width of the search strip can be calculated as shown above (section 2.3). The two values calculated based on the two different range measurements are supplemented with a recommended value for the width of the search strip. These values were chosen for ease of use and consider in particular the performance if other beacons than the VS 2000 are transmitting beacons, and the fact that the test results were obtained under ideal conditions which never prevail in reality. This affects in particular the one antenna acoustical beacons.

*Table 2: Results of medium range measurements. Mean and standard deviation given are for fitted normal distribution.*

| Type of beacon | N | Median (m) | Mean (m) | Standard deviation (m) |
|---|---|---|---|---|
| Mammut Barryvox optical | 126 | 21.7 | 21.6 | 2.8 |
| Mammut Barryvox acoust. | 128 | 42.0 | 41.8 | 5.3 |
| Ortovox M2 optical | 126 | 22.6 | 22.3 | 2.9 |
| Ortovox M2 acoustical | 128 | 61 | 62.5 | 11.8 |
| Tracker DTS | 127 | 20.7 | 20.6 | 2.0 |
| VS 2000 | 128 | 79.5 | 81.2 | 17.2 |

## 4. Discussion and Conclusions

We have comprehensively tested search time and range, two of the most important properties of a an avalanche rescue beacon. Special emphasis has been put on the test design which is considered as being exemplary for any future tests, in particular in regard to any bias caused by the learning curve of the test persons. The test results therefore show the state of art of avalanche beacons in winter 2001. We have not tested multiple burial situations, or explicitly ease of use, or other important features such as reliability.

The search times found have been quite small, i.e. even novices can find after minimal training a single buried beacon reasonably fast. Beacons with two antenna with optical search aids proved to have an advantage. Multiple burials have not been considered, but a good beacon must definitely be useful for this difficult situation. The search times of 1½ to 3½ minutes should be interpreted with caution. In a real situation search times might be substantially longer. In addition, digging out a person that has been caught and buried will easily take a few times longer. A quick test after the search time measurements showed that a group of four students needed 12 minutes to recover a dummy that was buried in 1.2 m depth.

The range measurements showed that the method proposed by Meier (2001) is well suited to determine the search strip width and produces relatively conservative values which is good. This is in part due to the fact that the method considers insufficient user co-operation. The method needs a smaller test sample and gives more repeatable values.

*Table 3: Results of maximum range measurements. Mean and standard deviation given are for fitted normal distribution.*

| Type of beacon | N | Median (m) | Mean (m) | Standard deviation (m) |
|---|---|---|---|---|
| Mammut Barryvox optical | 56 | 27 | 27.4 | 2.3 |
| Mammut Barryvox acoust. | 56 | 52 | 52.2 | 6.9 |
| Ortovox M2 optical | 56 | 27 | 26.9 | 3.9 |
| Ortovox M2 acoustical | 56 | 87 | 87.3 | 6.1 |
| Tracker DTS | 56 | 25 | 24.6 | 0.6 |
| VS 2000 | 56 | 107 | 107 | 6.2 |

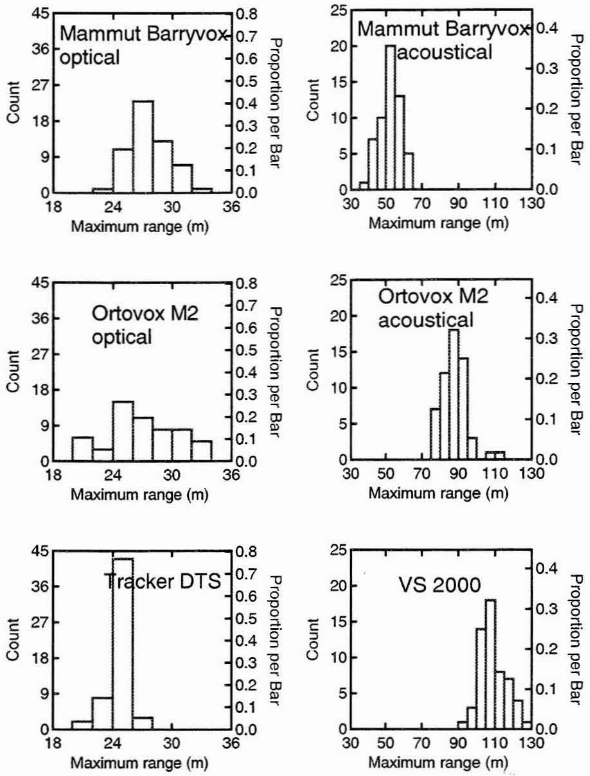


*Figure 6: Frequency distributions of maximum range measurements for the four different beacons tested.*

The results clearly show that the search strip width is a device specific property that should be specified on the beacon housing. However, since range is a promotional argument it is necessary to have a reliable method to quickly assess specifications given by manufacturers. The tests have shown that the method proposed by Meier (2001) is particularly suited for that purpose.

*Table 4: Results on the width of search strip. Three values are given. The first two values are calculated ones based on he range measurements. The third value is a non-committal recommendation.*

| Type of beacon | Width of search strip (m) | | |
|---|---|---|---|
| | Based on medium range | Based on maximum range | Recom-mended |
| Mammut Barryvox optical | 32 | 23 | 20 |
| Mammut Barryvox acoustical | 63 | 40 | 40 |
| Ortovox M2 optical | 32 | 20 | 20 |
| Ortovox M2 acoust. | 83 | 74 | 50 |
| Tracker DTS | 33 | 23 | 20 |
| VS 2000 | 100 | 94 | 60 |

On the 50 m × 70 m test fields the different range properties did not have a significant influence on search times, i.e. beacons with a shorter range did not produce slower search times.

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